TCD MONITORING OF CRITICALLY ILL PATIENTS

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DISCLOSURES

FTE, Private Practice for profit

I hope someone is monitoring my brain...

MULTIPLE PERSPECTIVES
CEREBRAL VASOSPASM AND ITS CLINICAL SIGNIFICANCE

Multimodal Monitoring
- MAP
- SaO2
- ECG
- Et-CO2
- CVP
- Urine output
- ICP
- CBFV/TCD
  - PbO2
  - cEEG
  - CT/MRI Perfusion

Specific TCD Applications for Critical Care
- Vasospasm diagnosis/monitoring and treatment effect evaluation after TBI, SAH, intracranial hemorrhage, tumor resection
- Stroke diagnosis/monitoring and treatment effect evaluation
- PFO screening for cryptogenic stroke and risk assessment
- Emboli and Fat emboli monitoring
- CEA/CAS effect evaluation
- Neuroradiology test-occlusion (pre, during and post)
- Neuroradiology stenting (pre, during and post)
- Pre- and Post-treatment AVM evaluation
- Septic patients evaluation
- Diagnosis and monitoring of intracranial hypertension
- Brain Death

Vasospasm
- SAH
- ICH
- IVH
- TBI
- Tumor resection
- Migraine with symptoms
- RCVS – Focal Stenosis? Vasospasm?
Cerebral Vasospasm and Delayed Ischemic Deficit
*N. Dorsch et al., 1994 and 2011*

- **1994**
  - Literature review of more than 30,000 cases
  - DID occurred in 32.3%
  - Outcome of DID:
    - Death in 30.3%
    - Permanent deficit in 34%
    - Good outcome in 35.7%

- **2011**
  - Literature review of 23,806 cases
  - DID occurred in 28.5%
  - The outcome of DID:
    - Death in 25.6%
    - Good outcome in 54.1%

Cerebral Vasospasm Clinical Significance

- Cerebral vasospasm constitutes a major complication of SAH
- The presence of vasospasm has been correlated with a 1.5 to 3-fold increase in mortality in the first 2 weeks after SAH
- DID occur during a period ranging from 4 to 12 days, but early (3d) or late manifestations (≤ 3 wk) may be observed

TCD DIAGNOSIS OF VASOSPASM

CBF Measurements

- Xe 133
- SPECT
CBF vs. CBFV

- $^{133}$Xe
- Stable xenon-enhanced CT
- MRI
- PET
- SPECT
- The time, expense, and complexity of these techniques still limit its use in routine clinical practice

TCD Diagnosis of Vasospasm

Newell et al., 1993

Diagnosis and Monitoring of Vasospasm: ANGIOGRAPHY

- Degree of angiographic vasospasm does not always correlate with the clinical condition. Some patients remain asymptomatic with severe vasospasm demonstrated by angiography
- Incidence of angiographic vasospasm is nearly twice that of DID

Diagnosis and Monitoring of Vasospasm: TCD

- High CBFV can identify patients at higher risk for developing DID, but also may occur in asymptomatic patients
- Neurologist/Neurointensivist must determine whether the severity and location of the vessel narrowing/high CBFV are appropriate to cause the clinical deficit
Transcranial Doppler in cerebral vasospasm

Newell et al., 1990

- MCA CBFV ≥ 120 cm/s: 25% narrowing
- MCA CBFV ≥ 140 cm/s: 25-50% narrowing
- MCA CBFV ≥ 200 cm/s: 50% narrowing

TCD Criteria for diagnosis of MCA vasospasm

<table>
<thead>
<tr>
<th>Mean CBFV (cm/s)</th>
<th>MCA/ICA ratio (Lindergaard Ratio)</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;100</td>
<td>&lt; 3</td>
<td>Nonspecific</td>
</tr>
<tr>
<td>100-140</td>
<td>3-6</td>
<td>Mild</td>
</tr>
<tr>
<td>140-200</td>
<td>3-6</td>
<td>Moderate</td>
</tr>
<tr>
<td>&gt;200</td>
<td>&gt;6</td>
<td>Severe</td>
</tr>
</tbody>
</table>

TCD criteria for vasospasm (mean CBFV)

- Newell D et al, 1990: 120 cm/sec = significant VSP on DSA
- Mascia L et al, 2003: TCD, threshold value of 100 cm/s for DSA VSP and 160 cm/s for clinical VSP detection
- Krejza J et al, 2005: 94 cm/sec with TCCS and DSA
- Razumovsky A et al, 1991-2013: 100 cm/sec with TCD

“Standard” TCD changes after vasospasm
SAH & ICP

- We are judging qualitative TCD wave form morphology changes
- These changes usually will be obvious after ICP will be more 20 mm Hg
- However, one condition must be fulfilled if you would be using TCD wave from changes to predict intracranial hypertension: MAP, cardiac output and PaCO2 are normal and not different significantly compared to the previous day

Prediction of symptomatic vasospasm after SAH with TCD

- An early CBFV increase (Seiler et al., 1988)
- A rapid CBFV increase in the first 6 days (Grote et al., 1988)
- A CBFV increase of at least 50 cm/sec during 24 hours (Grosset et al., 1993)
- A CBFV increase of 50 cm/sec during 48 hours (Wardlow et al., 1998)
- Relative changes in CBFV’s (two or threefold CBFV increase) in patients with aneurysmal SAH correlated better with clinically significant vasospasm than absolute CBFV’s (Naval et al., 2005)
Role of TCD: SAH

- Elevated CBFV's in asymptomatic patients warrant meticulous observation in some closely supervised setting until CBFV's begin trend downward.
- Elevated CBFV's in a particular vascular territory can focus subsequent neurologic examinations to detect subtle changes earlier in their clinical course.

Factors influencing interpretation

- Patient age
- The presence of moderate to severe anemia (Hct <27)
- Impaired CBF autoregulation (passive CBFV variation with MAP changes)
- Hyperemia induced by triple-H therapy

Role of TCD: SAH

- In symptomatic patients, elevated CBFV’s most likely represent significant vessel narrowing and may obviate the need for cerebral angiography. At this point, triple-H therapy can be initiated or advanced.
- Asymptomatic patients without elevated CBFV’s probably can avoid additional angiography. However, we need to consider patient’s age because elderly patient’s could develop vasospasm in normal or slightly abnormal CBFV range.

Factors influencing interpretation

- Patient age
- The presence of moderate to severe anemia (Hct <27)
- Impaired CBF autoregulation (passive CBFV variation with MAP changes)
- Hyperemia induced by triple-H therapy

Unilateral TCD changes after vasospasm

- Day 1
- Day 3
- Day 5
- Day 6
- Day 7
- Day 8

RIGHT

LEFT

More than 10 cm/s
Guidelines for the Management of Aneurysmal SAH  
*Stroke Council, AHA, 1994*

**Summary and Recommendations:**
1. SAH is a medical emergency...
2. CT scanning for suspected SAH is strongly recommended...
3. Selective cerebral angiography to document...
4. TCD is recommended for the diagnosis and monitoring of vasospasm, although the cerebral angiography may be required for definitive diagnosis

**TCD MONITORING OF VASOSPASM**

Angiography examination in patient with CommA aneurysm before and after aneurysm clipping

Angiography examination after transluminal angioplasty
Role of TCD: SAH monitoring

- It is useful to perform TCD test on admission (or ASAP after surgery) and perform daily TCD studies when patient is in the ICU
- The frequency with which TCD should be performed may be guided by patient clinical presentation, knowledge of risk factors for vasospasm, early clinical course
- TCD studies should be performed after endovascular treatment to identify patients with recurrent vasospasm

Role of TCD: SAH Monitoring

- The presence and temporal profile of CBFV’s in all available vessels must be detected and serially monitored
- The pattern of CBFV’s elevation may indicate the need to follow patient carefully for evidence of deficits related to specific vascular territory
- Waveform appearance either regionally, or globally may be clinically significant

2011 AHA/ASA Metrics for Measuring Quality of Care in Comprehensive Stroke Centers

- Among different measures for Comprehensive Stroke Centers is:

Median frequency of noninvasive monitoring for surveillance for vasospasm in patients with aneurysmal SAH during the period between three and 14 days after SAH

SAH

- Current medical therapy (nimodipine/nicardipine) or aggressive 3H-therapy will not prevent patients after aSAH or tSAH to have vasospasm
- Close to 100% of patients after aSAH and 60% after tSAH would have vasospasm demonstrated by cerebral angiography and/or TCD
- Early brain injury after aSAH emerges as a new recent concept with emphasis on complex pathophysiological mechanisms that are linked to initial bleed. However, it remains unknown whether global ischemia itself or subsequent events are responsible for the detected cell death and neurodegeneration
- Numerous experimental work going on trying to identify therapies for vasospasm prevention/treatment
### TCD and SAH

- Currently, the gold standard for vasospasm diagnosis is cerebral angiography, replaceable by CTA, only when angiography is not available. Obviously, it is not feasible to perform such investigation as frequently as bedside clinical assessment.
- Repeated clinical assessments of a patient’s neurological status carry the problem of detecting the clinical signs and symptoms of vasospasm, which occur only after vasospasm has already manifested its deleterious effects on the cerebral parenchyma.
- TCD is a relatively new, non-invasive tool, allowing for bedside monitoring to determine CBFV’s indicative of changes in vascular diameter.

- TCD can be useful pre-, intra- and post-operatively, while helping to recognize the development of cerebral vasospasm before the onset of its clinical effects.
- Vasospasm following SAH is a very important source of morbidity and mortality. Too often, the first sign is a neurologic deficit, which may be too late to reverse.
- TCD assists in the clinical decision-making regarding further diagnostic evaluation and therapeutic interventions. When performed in isolation, the contribution of TCD to improving patient outcome has not been established. Nevertheless, TCD has become a regularly employed tool in neurocritical care and perioperative settings.

### Do we know everything about TCD and vasospasm?

- TCD criteria for vasospasm for the young (less than 20-30 yo) and old (more than 68-70 yo) patients?
- CBFV calculation formula that will take into account Hct values
- Cerebral angiography could be negative but TCD could be positive for vasospasm
- No clear predictive value for patients who will have symptomatic vasospasm based on angio or TCD data developed

### Case 109-110. Rabies

**CBFV’s and Systemic Hemodynamic trends**

<table>
<thead>
<tr>
<th>Event</th>
<th>Right</th>
<th>Left</th>
</tr>
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<tbody>
<tr>
<td>High ICP episodes</td>
<td><img src="image_url" alt="Graph" /></td>
<td><img src="image_url" alt="Graph" /></td>
</tr>
</tbody>
</table>
**Case 109-110. Rabies**

Monitoring effect of treatment

Nov. 17, 2009 DAY 21

TCID SIGNS OF VASOSPASM/VASOPARESIS
07:51 AM

250mg of aminophylline - bolus, and 0.5mg x kg x Hr dripping.

Nov. 17, 2009
2:58 PM

Rt MCA CBFV 100/cm/sec; PI 0.6

**TCD CBFV changes**

**Increase**

- Vasospasm
- Hyperemia
- CBF autoregulation loss
- ↑ PaCO\(_2\)
- Intracranial arterial stenosis
- Increasing age (atherosclerosis)
- Altered collateral circulation
- Volatile anesthetic agents
- Sickle cell anemia
- Rewarming after hypothermia
- Arteriovenous malformation
- Bacterial meningitis
- Pre-eclampsia

**Decrease**

- Hypotension
- ↓ CBF
- ↓ PaCO\(_2\)
- ↓ angle of insonation
- Pregnancy
- Anesthetic Induction agents (except ketamine)
- Hypothermia
- Fulminant hepatic failure
- Raised ICP
- Brain death

**TCD PI changes**

**Increase**

- ↑ PaCO\(_2\)
- Hydrocephalus
- Traumatic brain injury
- Intracerebral hemorrhage
- Fulminant hepatic failure
- Stroke
- Intracranial artery occlusion
- Bacterial meningitis
- Early rewarming following hypothermia
- Encephalopathy
- Raised ICP
- Brain death

**Decrease**

- Vasospasm
- Vasoparesis
- Arteriovenous malformation
- Carotid-cavernous fistula
- Late rewarming following hypothermia
- Hyperemia
- Hypotension
- ↑ PaCO\(_2\)

**TCD is a Critical Tool (Quantitative Biomarker) in Critical Care**

- The use of TCD at hospital admission and later allows identification of patients with brain hypoperfusion due to the stroke, vasospasm after SAH/TBI and/or intracranial hypertension
- In such high-risk patients, early TCD goal-directed therapy can restore normal cerebral perfusion and might then potentially help in reducing the extent of secondary brain injury
- TCD could provide information about abnormally high ICP
- Incorporation of TCD data may facilitate more injury- and time-specific therapies for patients in Neuro-ICU
Clinical Value of TCD in Neuro-ICU

Detect a Change from Baseline and/or Normal Values Before Irreversible Damage Occurs

TCD Advantages

- Rapid assessment of cerebral vasculature, provides physiological and hemodynamics data
- Quantitative
- Repeatable
- Changes often precede clinical symptoms
- Changes precede angiographic narrowing

TCD Advantages

- No contraindications
- Portable
- Non-invasive
- Safe and not painful
- Cost-effective alternative to radiographic choices

TCD is a Critical Tool in Critical Care

- The high sensitivity of TCD to identify abnormally high/low CBFVs and PIs due to the onset of vasospasm/ischemia and intracranial hypertension, respectively, demonstrates that TCD is an excellent first-line examination to determine those patients who may need urgent aggressive treatment and continuous invasive ICP monitoring
- Because vasospasm and intracranial hypertension represent significant events in a high proportion of patients after hemorrhage and TBI, respectively, daily TCD monitoring is recommended for the management of such patients
TCD “Disadvantages”

- Operator dependency: myth
- N. American medicine relies on imaging very broadly vs. physiological data interpretation: true and
- Neuroimaging modalities utilization and overutilization: very true
- Absence of structured teaching: true
- Absence of credentials for sonographers who are doing TCD exams